SAND2016-3409C

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

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WEC and Support Bridge Control Structural Dynamic Interaction Analysis

ABSTRACT

Experimental testing is a critical step in the development of models describing the behavior of a system. The objective of the experimental testing presented in this document is to obtain models for the design of control systems in realistic environments for a Wave Energy Converter (WEC). The particular WEC considered here is a heaving point absorber composed of a floating buoy (see Fig. 1) connected to a support structure through a linear actuator. The support structure is then attached to the side of a bridge (see Fig. 2). The testing will be conducted at the Maneuverability and Seakeeping (MASK) basin located at the Naval Surface Warfare Center Carderock Division (NSWCCD), Bethesda, MD.

The actuator applies a force between the floating body and the support structure in order to absorb power from waves. The simplest control strategy that is commonly used for power absorption is linear damping, where the force applied by the actuator is proportional to the velocity of the buoy; in practice, this constitutes a very simple static feedback (no dynamics in the feedback loop)

$$F_u = -B\,v$$

where F_u is the actuator's force, v is the velocity of the buoy and B is the damping coefficient.

The support structure cannot be assumed to behave as a fixed reference, thus the actuator connects two oscillating structures (the bridge/support structure and the WEC). Both a modal analysis and experimental testing have been conducted by ATA Engineering on the bridge in order to study the dynamical response of the bridge. Figure 5 depicts the frequency response function (FRF), and it can be seen that the lowest two modes of interest (vertical bending and torsional) are very close to the range of frequencies that will be used for the testing of wave-body interactions by means of waves in the range of 0.4-1.0 Hz. The objective of this paper is to analyze the potential adverse effects of having a feedback control system applied between these two structures that have close resonance frequencies, and to propose a control design solution for the mitigation of these interactions.

Fig. 1: Floating buoy (designed and fabricated by SNL)

KEY POINTS:

- Identified a method to accommodate Control-Structure Interaction (CSI) between WEC and support bridge
- CSIs are part of the real life scenarios needed to be overcome
- Shaping filters can be used to minimize effects of CSI.
- A simple notch filter was proposed to stabilize the response and allow for minimal power loss during resonance

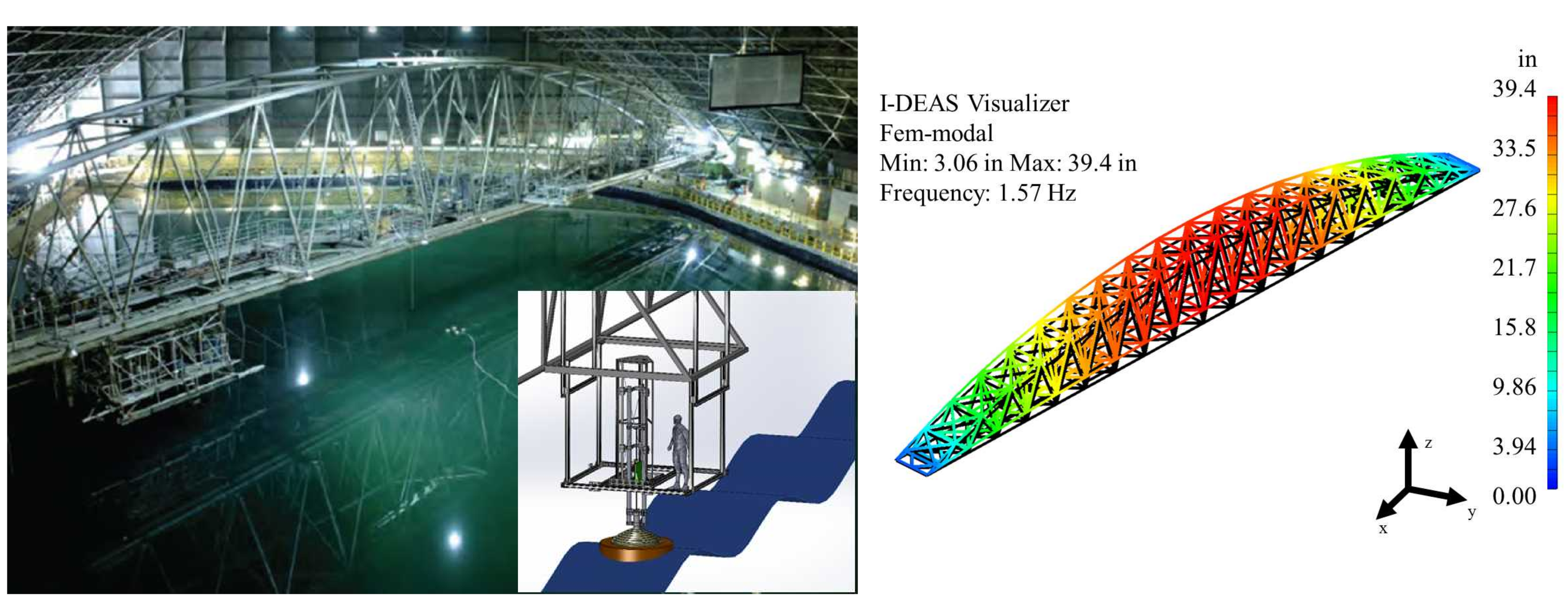

Fig. 2: Maneuverability and Seakeeping (MASK) basin,
Naval Surface Warfare Center Carderock Division (NSWCCD), Bethesda, MD

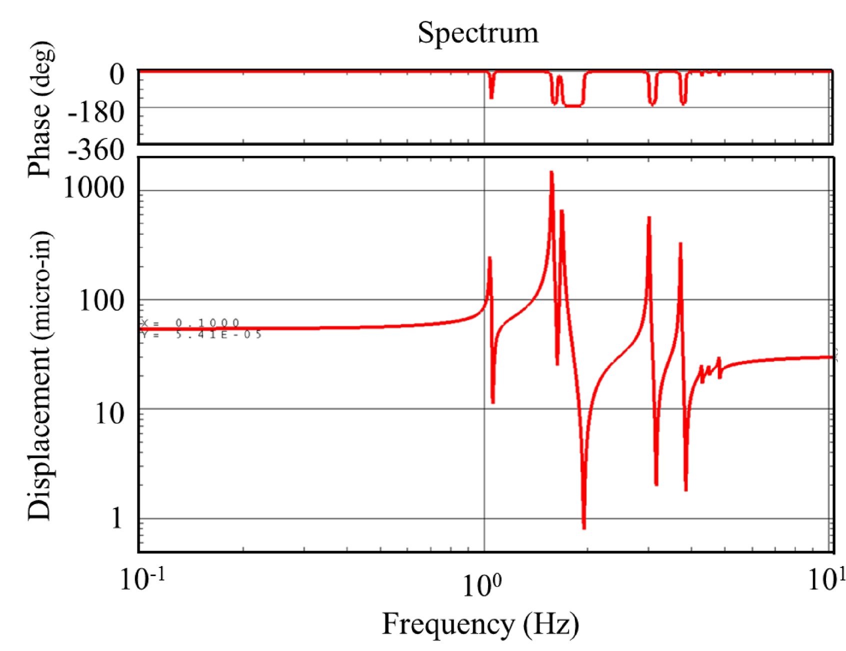

Fig. 3: Bridge FRF (FEA)

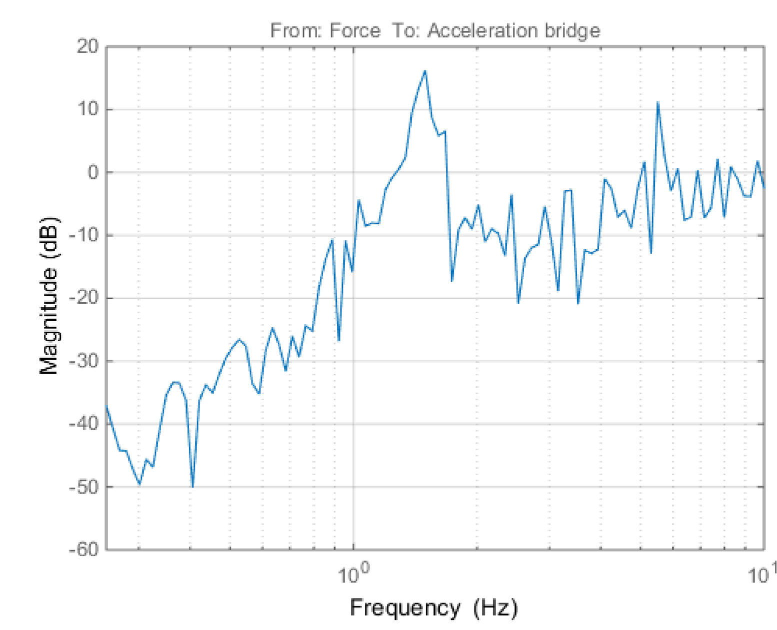

Fig. 4: Bridge FRF (Experimental)

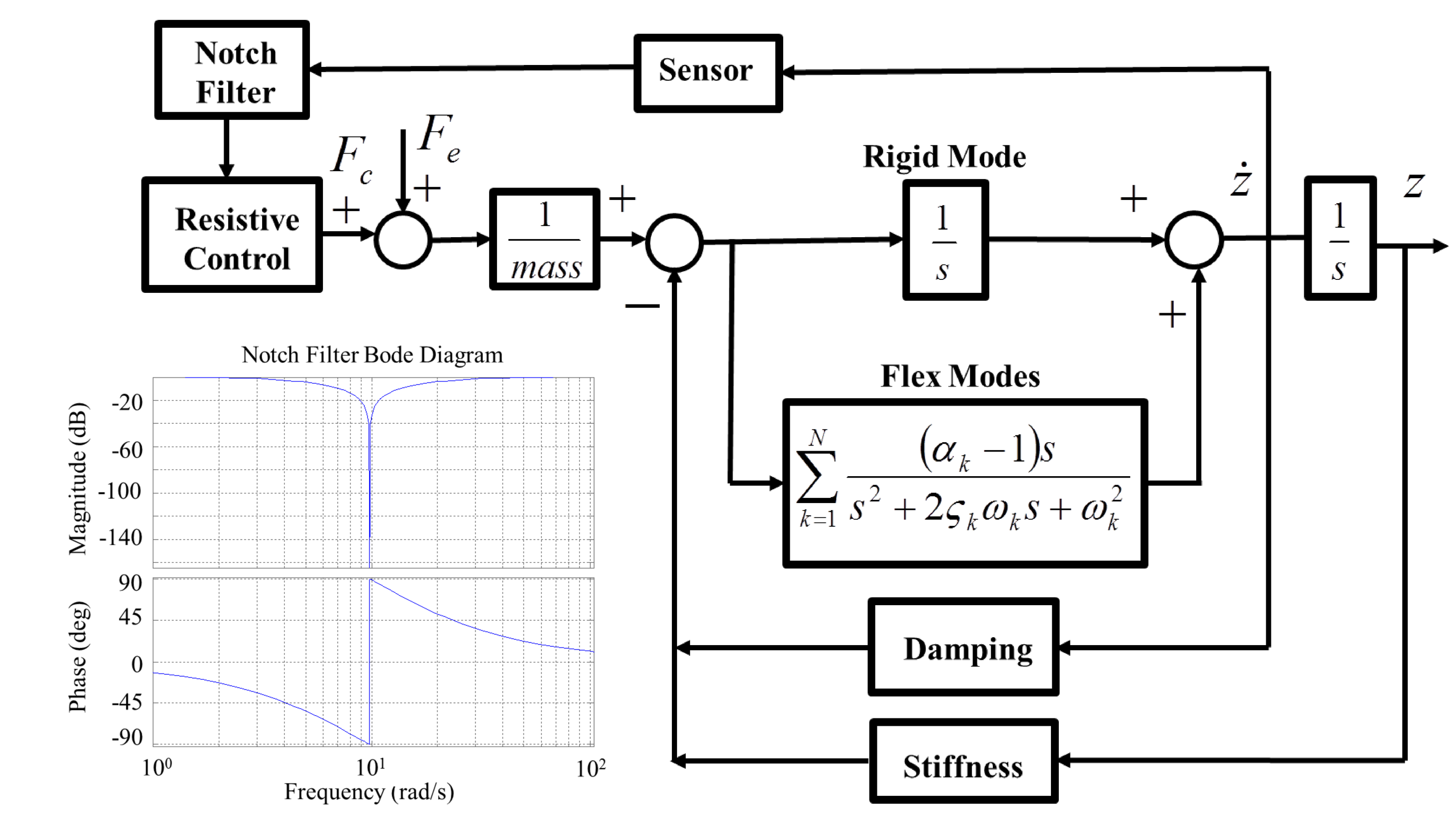

Fig. 5: System Block Diagram

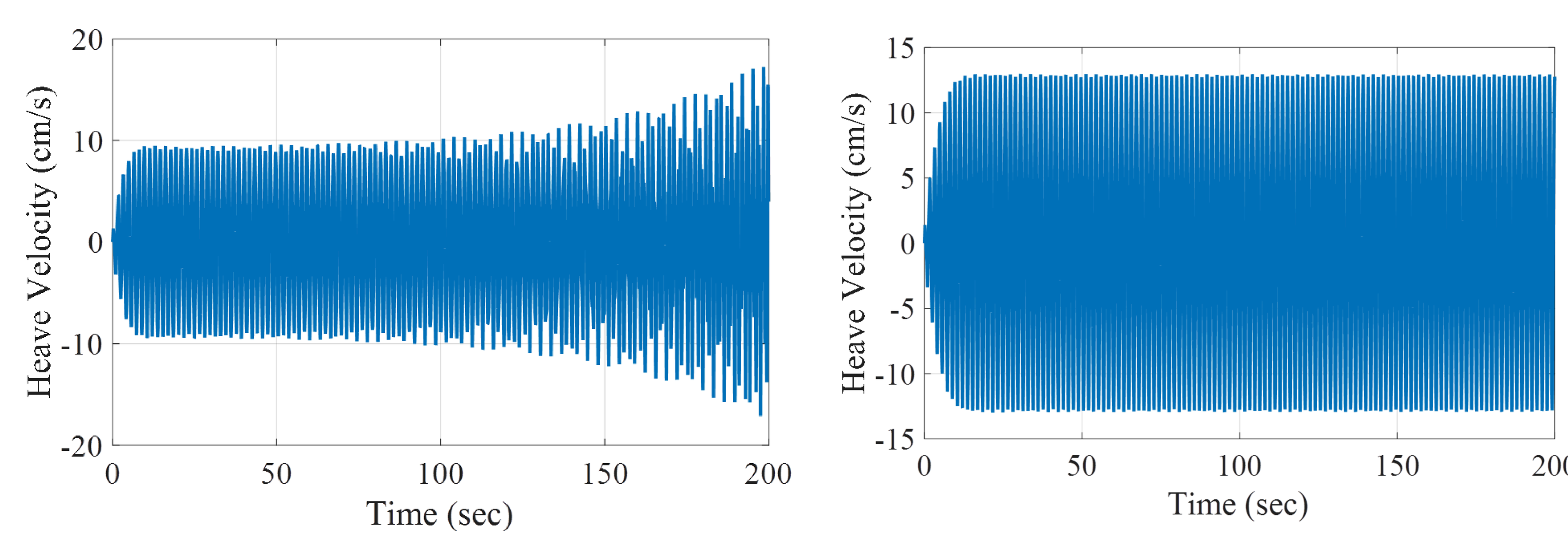

Fig. 6: Simulated response without notch filter (left) and with notch filter (right)

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ACKNOWLEDGEMENTS

The authors would like to thank Kevin Dullea, David Patterson and Mark Monda of SNL for the hardware development and experimental support of the WEC system heaving point absorber. We would also like to thank Patrick Barney of SNL and James Freymiller of ATA Engineering, Inc. for their consultation on bridge structural dynamics model. This work was funded by the U.S. Department of Energy's Wind and Water Power Technologies Office. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.